# Research and Operational Use of Environmental Satellites in Weather Applications as Part of an Integrated Earth Observing System

Environmental satellites have become an increasingly vital component of the global observing system for climate monitoring and weather prediction. Therefore, steps must be taken to ensure that their role is both sustained and enhanced to provide a cost effective and flexible satellite constellation that is the centerpiece of an advanced integrated Earth observing system. Over the past quarter century, major advances in satellite technology and instrumentation have translated into increased usage by the weather and climate-related industry. In particular, weather services and other environmental agencies including research organizations throughout the world have become increasingly reliant on remote sensing data from these satellites. High-impact weather events such as hurricanes and severe storms are continuously monitored by this essential component of the observing system. Since the late 1990s, a wide variety of advanced-capability environmental remote sensing satellites have been deployed with many applications to weather forecasting, climate, hydrology, oceanography, land use and related applications. At the same time, the satellite data processing infrastructure has become more affordable and dependable with advances in network speed and reliability, Internet access, online high-volume data storage, and processing algorithms. This has opened up the access of data for increased utilization in the private, public, and educational sectors.

International programs such as IGOS (Integrated Global Observing System) and THORPEX (a Global Atmospheric Research Program) are developing new strategies that will most likely lead to improved weather prediction in the coming decades. The constellation of environmental satellites capable of weather applications will be a strong contributor to these new visions. With this in mind, the American Meteorological Society urges the following actions:

**Maintain uninterrupted operations and global coverage of the Earth from geostationary- and low Earth-orbiting environmental satellites while moving toward an advanced integrated Earth observation system.** Global weather forecast operations are dependent upon the rapid-time update and fine spatial resolution available from geostationary-orbiting (GEO) visible-to-infrared (VIS/IR) imaging systems. Weather analysis and short-range forecasting have benefited from the ability to rapidly process and animate these data. The GEO imagery also serves an important role by providing a reliable and routine method of communicating present weather conditions to the public through television and the Internet. Complementing the GEO observations, the many advanced sensors now flown on low Earth-orbiting (LEO) satellites provide vital measurements of the Earth’s surface and atmosphere for numerical weather prediction (NWP) systems. These sensors provide spectral coverage that is not available from GEO satellites. The importance of maintaining an operational suite of LEO passive microwave (PMW) sensors is especially stressed, since these data are uniquely capable of measurements that can directly monitor the Earth’s hydrological cycle and associated climate variabilities. The inclusion of LEO multispectral radiance measurements into NWP models has contributed significantly to the improvement in forecast accuracy. In summary, operational weather satellite programs must be sustained and the sensors advanced in order to better initialize increasingly sophisticated NWP models. At the same time, the sensor technology must be kept flexible enough to provide complimentary information that is consistent with previous satellite-derived climate data records and analysis.

**Continue coordination of both the national and international satellite agencies and encourage open access to these data.** It is imperative to maintain free and timely access to the most current satellite-derived information. Many of the advances in both forecasting the local weather and understanding the global climate have occurred because a diverse scientific and user community had open access to global satellite observations. It is critical that civilian, military, and commercial entities in the United States and other nations continue to work together to provide open access to remote sensing data. This will ensure against unnecessary data voids, enable continued benefit from the positive impact of the data on the accuracy of global weather predictions, encourage the use of the data by cross-cutting disciplines in the broad scientific community, and foster the development of universal algorithms and services that eventually can result in the saving of life and property. It must be stressed that unfettered access to environmental satellite data will require vigilance, generosity, and vision by the scientific community and political leaders alike.

**Accelerate the transition of promising satellite-based technologies from research to operations**. We applaud the satellite agencies recent goals to address this issue. An encouraging trend has been the adaptation of satellites that were originally planned for research missions into platforms that provide valuable operational data in near-realtime. However, in order to realize gains in forecast accuracy from promising research satellite measurements, an effective "bridge" needs to be in place to facilitate the transition to operational data usage. A primary issue is the one of instrument procurement. Currently, the agencies develop plans often on decadal time scales (procure a fixed instrument suite for a satellite "generation"). While these "package" plans are motivated by fiscal incentives, they have not traditionally allowed for "discoveries" or rapid technological advances from research satellites. It is our view that industry and procurement agencies need to work together to develop much shorter time-scale deployment strategies. A National Resource Council committee report ("Satellite Observations of the Earth's Environment: Accelerating the Transition of Research to Operations") published in 2003 stresses these concepts and recommends potential solutions. We support the principles outlined in this report and encourage the satellite agencies to consider the findings.

**Support the R&D needed to promptly advance the data and products from "next-generation" satellite sensor systems into operational applications.** In recent years, environmental satellite sensors have become more effective due to advancements in aerospace and electromagnetic technologies. Hyperspectral imaging spectrometers, all-weather (except for the very heaviest precipitation) GPS radio occultation measurements, and active sensors such as lidar and space-based radar are examples of the "next generation" of sensors that are already emerging, or planned for deployment this decade. These new measurements will require innovative research and development of multisensor (and increasingly, multi-satellite) retrieval techniques. Weather service institutions with operationally-oriented missions rely on robust research and development programs to effectively demonstrate the usefulness and reliability of new science and technology. We must accelerate the incorporation of these new measurements into weather forecast services, climate, hydrological, oceanographic, and other environmental applications for use by appropriate government, university, and private sector institutions. Therefore, we strongly advise that appropriate resources be advocated to these R&D programs devoted to the optimal utilization of new remote sensing measurements, both before and after deployment.

**Increase the flexibility of satellite sampling strategies.** With the increased sophistication of weather satellite instrumentation packages and capabilities, we advise the satellite agencies and associated ground station data processing facilities to develop plans to allow for greater "adaptive sampling" strategies. The motivation for this comes from the satellite data user community, whom is increasingly stressing the desire for "targeted" observations. This concept involves the special sampling of selected meteorological events (or limited tropospheric regions) that may produce high-impact weather or contribute to poor NWP forecasts. In regards to observations from satellites, the targeting may involve more frequent sampling, higher spatial resolution, or spectral enhancements, all focused on the region of interest. We encourage the satellite instrument engineers to develop efficient on-board processing and data decompression capabilities to support data selection strategies during adaptive sampling periods. This will become critical in the emerging era of hyperspectral sensing and very large data volumes. Concurrently, satellite data receiving stations can implement more flexible data acquisition schedules so routine operational image scanning (or data collection) is not affected during special observing periods.

**Protect important space-based remote sensing spectral bands from terrestrial usage and interference.** The protection of microwave frequencies for passive remote sensing from space against possible harmful interference from active Earth-based radio communication services sharing the same spectral bands is essential for safeguarding and further developing environmental sciences, which include operational meteorology, hydrology, and oceanography. Primary frequency allocations have to be protected and exclusive where needed, or associated with adequate power limits if sharing spectral bands with active radio communication services. This is especially relevant for those PMW imaging/sounding spectral bands that are currently under threat from terrestrial navigation and personal communications systems. Since many climate data records have been gathered using these PMW data since the 1980s, interference within these bands will compromise our ability to extract potential climate signals in the future. We encourage and support international efforts to secure and/or obtain the required primary allocations and protection criteria from World Radiocommunication Conferences of the International Telecommunication Union (ITU), which would ultimately reserve these important bands for environmental remote sensing.

**Stress the importance regarding accurate calibration of satellite measurements.** Global satellite observations over the last two decades have contributed to a better understanding of climate variability and the effects of natural and man-induced processes on the environment. As stressed throughout, maintenance and improvement of global satellite systems have become critical necessities for sustaining and enhancing weather and climate prediction services and for monitoring global surface and tropospheric temperature, ozone, precipitation, and cloud properties. However, without precisely known and consistent calibration of multiple instruments over time, the small signals often associated with phenomena such as climate change may not allow proper interpretation. Satellite data calibration intercomparisons provide a means to ensure that the measurements from individual satellites are consistent with one another. We applaud efforts by the weather satellite data providers towards improving sensor capabilities, but also stress that adequate intercalibration studies must be done (pre and post launch) in order to maintain the consistency necessary for long-term observational analyses.

**Emphasize education and promote online training in the use of environmental satellite remote sensing data and products in weather applications.** The variety of satellite data available for weather and climate analysis with each passing year is increasing, with finer spatial resolutions, expanded spectral capabilities, faster refresh rates, etc. Keeping up with the evolving capabilities and applications that these data can provide requires a modern and ongoing educational infrastructure. From an operational standpoint, the forecast community needs to be kept abreast of new developments in satellite-based applications. On the academic side, it is important that the nature and optimal use of satellite remote sensing data be incorporated into the educational curricula for atmospheric sciences at both the college and pre-college levels. While both the AMS and the federal government have laid the foundation for promoting meteorological education for both students and science teachers at these levels, significant emphasis on satellite remote sensing needs to be expanded into the primary grades to stimulate greater interest in meteorology at these earlier grade levels. The Internet is an ideal medium for the dissemination of online training programs, video presentations, animations, and graphical analysis. We encourage the satellite data providers, product developers, and researchers to further develop and coordinate online training programs so that users can quickly locate the most up-to-date information and relevant training material.